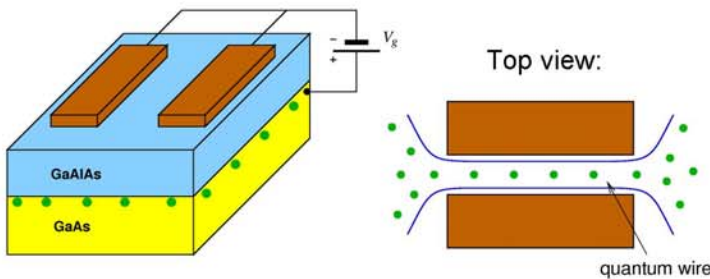


# Conductance of a quantum wire at low electron density

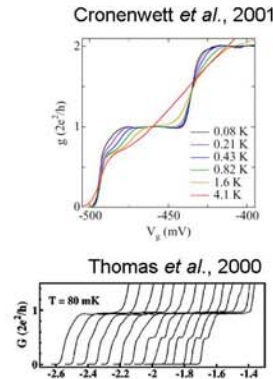
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We study the effect of Coulomb interactions on the conductance of a single-mode quantum wire connecting two bulk leads. When the density of electrons in the wire is very low, they arrange in a finite-length Wigner crystal. In this regime the electron spins form an antiferromagnetic Heisenberg chain with exponentially small coupling  $J$ . An electric current in the wire perturbs the spin chain and gives rise to a temperature-dependent contribution of the spin subsystem to the resistance. At temperatures small compared to  $J$  this effect is weak, and the conductance of the wire remains close to  $2e^2/h$ . At temperatures above  $J$  the spin effect reduces the conductance to  $e^2/h$ .

## Motivation: Experiments with Quantum Point Contacts and Quantum Wires



Typical experimental setup. The wire is created by electrostatic confinement of electrons to one spatial dimension.



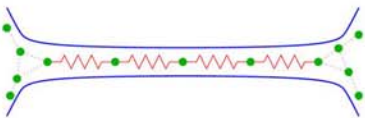
- Perfect conductance quantization at low temperatures ( $2e^2/h$ )
- 0.7 structure in conductance of quantum point contacts at low density and higher temperatures
- 0.5 plateau of conductance in longer wires
- These features cannot be explained in a model of non-interacting electrons

## Theory: Wigner crystal state of electrons in a Quantum Wire

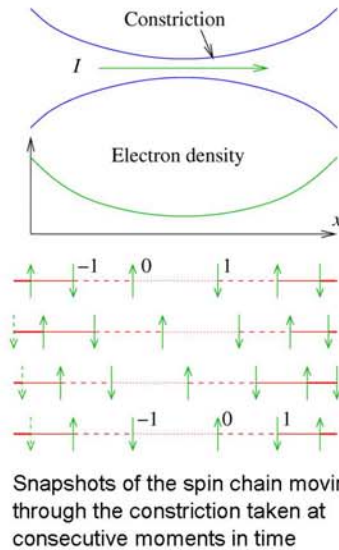
Compare kinetic and interaction energies of electrons at low density  $n$

$$E_{\text{kin}} = \frac{\hbar^2 k_F^2}{2m} \propto n^2, \quad E_{\text{Coul}} = \frac{e^2}{r} \propto n.$$

Coulomb energy dominates. To minimize it, electrons in the wire form a **Wigner crystal** state



The spins of electrons are very weakly coupled to each other, and form a Heisenberg spin chain



Because the electron density in quantum wire devices is not uniform, there is no spin-charge separation, and spins contribute to the resistance of the device:

$$R = \frac{h}{2e^2} + R_{\text{sp}}$$

## Results

1. Low temperature:  $T \ll J$

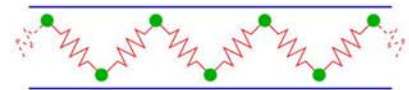
Spin excitations pass freely through the wire and do not affect conductance,  $G = \frac{2e^2}{h}$

2. High temperature:  $T \gg J$

Spin excitations are reflected by the wire and double its resistance,  $G = \frac{e^2}{h}$

## Future directions

- **Short quantum wires.**  
Can a similar spin effect explain the 0.7 structure in Quantum Point Contacts?
- **Double-row crystal.**  
Is the conductance doubled when we have 2 rows?



K. A. Matveev, *Phys. Rev. Lett.* **92**, 106801 (2004); *Phys. Rev. B* **70**, 245319 (2004).